

Traffic Safety at Road–Rail Level Crossings Using a Driving Simulator and Traffic Simulation

Inhi Kim, Gregoire S. Larue, Luis Ferreira, Andry Rakotonirainy, and Khaled Shaaban

Several intelligent transportation systems (ITS) were used with an advanced driving simulator to assess its influence on driving behavior. Three types of ITS interventions were tested: video in vehicle, audio in vehicle, and on-road flashing marker. The results from the driving simulator were inputs for a developed model that used traffic micro-simulation (VISSIM 5.4) to assess the safety interventions. Using a driving simulator, 58 participants were required to drive through active and passive crossings with and without an ITS device and in the presence or absence of an approaching train. The effect of changes in driver speed and compliance rate was greater at passive crossings than at active crossings. The slight difference in speed of drivers approaching ITS devices indicated that ITS helped drivers encounter crossings in a safer way. Since the traffic simulation was not able to replicate a dynamic speed change or a probability of stopping that varied depending on ITS safety devices, some modifications were made to the traffic simulation. The results showed that exposure to ITS devices at active crossings did not influence drivers' behavior significantly according to the traffic performance indicator, such as delay time, number of stops, speed, and stopped delay. However, the results of traffic simulation for passive crossings, where low traffic volumes and low train headway normally occur, showed that ITS devices improved overall traffic performance.

In the United States, empirical formulas based on historical accident data at level crossings have been used to predict the expected crash rate. These formulas, such as the Peabody–Dimmick formula, the New Hampshire index, the NCHRP crash prediction formula, the U.S. Department of Transportation crash prediction formula, and the Mississippi and Ohio methods, consider the crash history as well as some of the causal factors in determining the crash rate at a particular crossing. While a hazard index is a relative ranking, the crash prediction models calculate the actual frequency of crashes at crossings (1). Statistical collision prediction models are used to assess how specific countermeasures act to reduce collisions at specific grade crossings. In Australia, the Australian level-crossing assessment model is used to identify contributing risk factors at level crossings. This tool can be used to prioritize the level crossings that are to be upgraded.

Although the procedure for archiving crash data appears to have become more systematic, it often contains significant discrepancies. Many crash-related organizations, such as police, insurance companies, and bureaus of statistics, collect crash data in different ways. Police reports are prone to underreported bias. Elvik and Mysen analyzed crash recording rates in 13 countries (2). In their study, only 95% of fatal crashes, 70% of serious injury crashes (hospitalized), 25% of slight injury crashes (outpatients), 10% of very slight injuries (sent home), and 25% of property-damage-only crashes were reported, compared with the real accident frequency. Mills et al. investigated vehicle collisions and injury risk by using not only police records but also insurance data in Canada (3). They concluded that the number of collisions and injuries from the insurance data was far higher than that from the police record. This result suggests that an inconsistency in police accident records should be taken into account when other sources of accident data are not available.

Although emerging technologies and innovative roadside interventions have been introduced to change driver behavior (4), there is a lack of research on the integration of various intelligent transportation system (ITS) technologies and transportation simulation with a driving simulator to assess their influence on driving behavior. Constructing overhead bridges or underpasses is the best way to secure safety at railway crossings. However, local governments and councils cannot afford the cost when they have higher-profile priorities on which to spend their annual budgets. Upgrading crossings from stop signs or rumble strips to flashing lights and boom barriers is financially burdensome for some governments, especially if there are several crossings in a region. Evaluation of the danger level of railway crossings is important in decisions related to the spending of taxpayers' money. Instead of high levels of infrastructure spending, ITS devices can be used to warn drivers of approaching trains and to help drivers comply with road rules when approaching and using a rail crossing.

No studies used transportation simulation to identify the safety of a specific system. Most crash models regarding railway crossings are based on historical records, which are input into statistical models. In addition, driving simulator-based studies have not been used to identify the causes of crossing collisions, although a significant amount of research has been conducted on road safety (5–7).

In this study, various scenarios have been designed for the driving simulator so that an approaching train, vehicular traffic in the proximity of railway crossings and the infrastructure (e.g., road type)

surrounding railway crossings, and in-vehicle devices are as realistic as possible. To determine the performance of the ITS devices at railway crossings, the driving simulator was used to collect the stopping distances, approaching speeds of vehicles, and compliance rates with a sufficient degree of accuracy. Traffic microsimulation was also used to assess traffic safety that might be affected by the ITS device installation. This framework will examine whether driver compliance with stopping requirements at railway crossings equipped with ITS devices will perform better than only the usual controls at rail crossings. As part of the project funded by Cooperative Research Centres for Innovation (Australia), this study focused on how the different types of drivers respond to different types of ITS interventions (visual, sound, marker) and what traffic conditions would be expected under these research settings.

Use of Driving simulator and traffic simulation for railway crossings

It is obvious that collecting real field data is the best way to analyze different driving behaviors when different safety devices are tested. However, the number of events in which a train and a vehicle overlap in the same time and space fortunately is very low. Use of a driving simulator is a good alternative for creating as many events as possible to obtain reliable data (8, 9), although some shortcomings such as a limited fidelity and validity of simulator and sickness were reported (10).

Many recent studies in Australia on driving behavior at railway crossings have used a driving simulator. For example, Tey et al. compared driving behaviors from field data and a driving simulator for compliance rate, speed profile, and final braking position at railway crossings equipped with a stop sign, flashing lights, and half boom barrier (11). In another study by Tey et al. (12), four warning devices—flashing lights, in-vehicle warning, rumble strips, and stop sign—were tested according to the age and gender of the participants. Tey et al. used a fixed driving simulator to identify compliance rate, driver accelerator release position, and initial and final braking positions. Lenné et al. conducted an experiment to compare railway crossings equipped with a stop sign, flashing lights, and traffic lights in a driving simulator and concluded that traffic signals alone provided adequate warning to drivers (8). Rudin-Brown et al. extended their previous study by identifying the effectiveness between traffic lights and flashing lights with boom barriers at railway crossings using the same simulator (13). Their results revealed that traffic lights were not superior to flashing lights with boom barriers in safety benefits.

Traffic simulation has gained increasing popularity in traffic safety assessments. Traditional methods, such as statistical models and before-and-after comparisons, have been difficult to assess accurately, mainly because of the short length of an observation period, sample size problems, and reporting errors or missing data (14). The use of microscopic simulation with surrogate traffic conflict measurements offers an enhanced way of conducting safety evaluation without interrupting existing traffic conditions (15). Simulation-based surrogate safety measurements identify not only the probability of collisions but also the severity of these potential collisions.

Using a driving simulator with traffic simulation, this study attempts to discover how drivers react to various ITS safety devices and how these in turn determine driving behaviors, which may then affect traffic conditions. This paper is structured as follows. The next section briefly describes the procedure and scenarios tested in the driving simulator. Then the model development steps are set out to demon-

strate what has been modified in traffic simulation. The section on results first details the results of the driving simulator (as input for the modified traffic simulation) and then provides the results from the developed model so crossings with various traffic conditions along with ITS interventions can be evaluated. The discussion section explains what was found beyond the results. The final section concludes the main findings and suggests areas for future study.

Driving simulator

Participants

Advertisements for participants were placed on an online campus notice board and were also posted to Facebook for recruitment outside of campuses. A maximum of three experiment subjects were used per day. Fifty-eight participants, 39 men and 19 women age 19 to 59 years (mean = 28.2; standard deviation = 7.63), agreed to take part in the study. Participants were divided into three groups, with each group testing one particular ITS intervention. The first group, consisting of 20 participants, tested the visual in-vehicle ITS. The second group, consisting of 19 participants, tested the audio in-vehicle ITS. The last group, consisting of 19 participants, tested the on-road flashing marker system.

Driving simulator setup

Participants were asked to drive three itineraries consisting of several active and passive crossings (shown in Figure 1) with and without an ITS device and in the presence or absence of an approaching train. Drivers rely on warning flashing lights at the active crossing, and they must make a decision about whether to stop at the passive crossing. Drivers followed the speed limit of 40 km/h in the city area, 80 km/h on some portions of the road, and 60 km/h in most sections of the road. Crossing geometries and signage designs were based on the Australian standards (16). Three trials were implemented (Figure 2): video in vehicle (ITS1), audio in vehicle (ITS2), and on-road flashing marker (ITS3). ITS2 used the speakers of the simulator positioned inside the car (under the seat) to provide warning messages, such as “Train approaching the crossing ahead” and “Stop at the crossing.”

A road map of the Brisbane central business district in Queensland, Australia, as well as one of the surrounding road networks was used; this route included several railway crossings. Each driver encountered eight crossings (passive or active crossings were chosen randomly) per itinerary. Because participants drove three different itineraries, a total of 24 profiles per driver were collected.

modified traffic simulation

Preprocessing for gender and age

The distribution of gender and age in Queensland, Australia, was obtained from the number of driving licenses currently held (17). There were 1,612,887 males and 1,519,454 females. As Table 1 shows, males were allocated to Profiles 1, 2 and 3, and females were allocated to Profiles 4, 5, and 6. Profiles 1 and 4 included those younger than 20 years, Profiles 2 and 5 included those age 30 to 40 years, and Profiles 3 and 6 included those more than 50 years old. Whenever VISSIM detected a vehicle that held more than 5 s headway, the vehicle was regarded as a leading vehicle. The leading

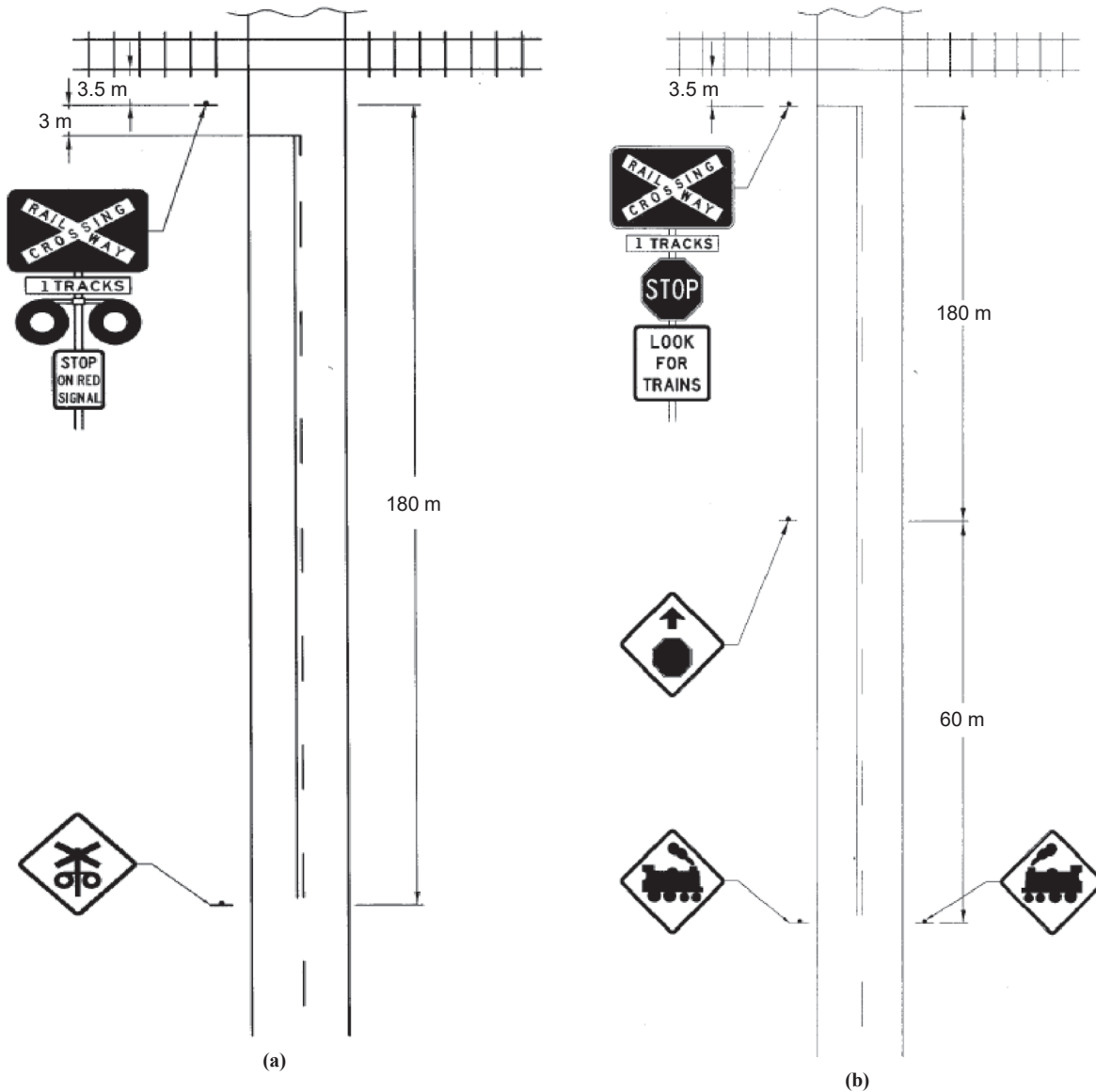


FIGURE 1 Crossings: (a) active and (b) passive (16).

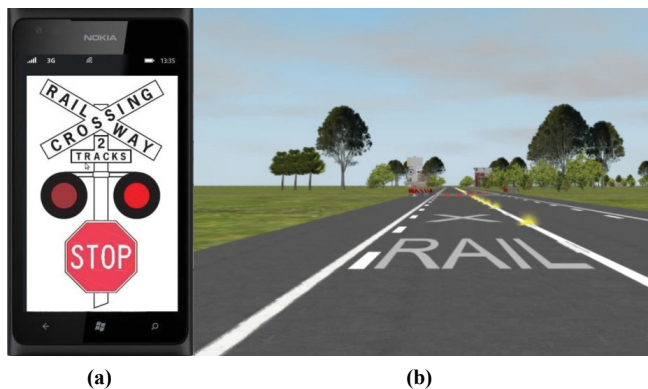


FIGURE 2 ITS devices: (a) video in vehicle and (b) on-road flashing markers.

vehicle then followed the speed profile derived from the driving simulator. The specific speed profile number was based on gender and age group, as shown in Table 1.

evaluation tool Using vissim com interface

The VISSIM COM interface allows the developed model to be enhanced through adjustment of the objects, methods, and properties in the default VISSIM. This application provides traffic engineers with a lot of freedom in the analysis of a variety of projects (18, 19). Like other traffic simulation software, VISSIM also allows access from an external interface.

The VISSIM COM interface also enables the automation of certain tasks. For example, to ensure a good quality of model calibration, multiple runs of scenarios are performed by changes in the random seed number. An external program, such as Excel or VBA,

TABLE 1 Group Categories

Profile	Male			Female		
	1	2	3	4	5	6
Age (years)	Younger than 20	30 to 40	Older than 50	Younger than 20	30 to 40	Older than 50
Percentage	12	19	20	12	19	18

can automatically increment the seed number sequentially so that the VISSIM results can be balanced.

Because of a limitation (e.g., control of speed at certain locations, a probability of stopping categorized by demographic) in the use of the current traffic simulation, some external controls must be implemented. In this case, for example, only the behavior of the leading vehicle needed to be changed according to what was observed from the driving simulator. The follow-on vehicles then had to be moved by the car-following theory that mainly controlled all the vehicles in the simulation.

vissim setup

The developed simulation model contained train tracks, roads, and various types of vehicles, detectors, and signals. Train tracks ran north and south, and roads intersected these train tracks horizontally. In this study, the simulation model was designed for two situations: an area where trains run frequently (an urban area) and an area where trains run relatively less frequently (a suburban area).

The simulation ran for 1 h (3,600 s) in intervals of 1 s for the urban area and 10 h for the suburban area. For the urban area the active crossing characteristics were applied, whereas for the suburban area passive crossing characteristics were considered.

In the urban area (active crossing), trains passed every 3 min for the peak hour, and vehicles were input to the network at 800, 1,000, and 1,500 vehicles per hour (vph). In the suburban area (passive crossing), 17 trains passed the crossings per day (10 h), and vehicles were introduced to the network at 200, 250, and 300 vph. Three detectors played a role in triggering a virtual signal control so that warning devices were activated accordingly.

With these data used as input for a traffic microsimulation model, a sample network was developed to identify how vehicles would react to the railway crossing equipped with base (control), ITS1 (smart phone), ITS2 (audio), and ITS3 (flashing markers on the road). A signal head function in VISSIM was adopted as the stop line at the railway crossings. Vehicles moved from the left to the right and were recorded every second.

Before the modified model was run, speed profiles were pre-processed according to the driving simulator's results. There were two sets of speed profiles: in the cases of an approaching train (speed profile 1) and no approaching train (speed profile 2). Each speed profile consisted of 20 average speed values measured every 5 m for 100 m from the crossing. Also, standard deviation values for each speed were taken into consideration.

As shown in Figure 3, the loop between start and finish continued running every second. The modified model detected whether a vehicle was a leading (subject) vehicle by calculating the headway. A detector located 120 m from the stop line checked the traffic headway. In the studied case, 5 s was used. A headway of traffic more than 5 s was considered a leading vehicle approaching the rail-

way crossing. The vehicle traveling 5 s after the last vehicle became the leading vehicle when it reached the detector, representing how the subject in the driving simulator responded to various situations.

At the same time, the model detected whether a train was approaching the crossing. When there was no train in the network, the subject vehicle held speed profile 2. If the train passed detector 1 (train approaching), the subject vehicle changed its speed to that of speed profile 1. Then, the model checked whether the subject vehicle complied with the traffic rules. A binary response that was randomly generated on the basis of the compliance rate of the driving simulator results was produced. If the binary response was 1, the subject vehicle complied. During the simulation run, the value (1 or 0) changed dynamically according to the compliance rate calculated from the driving simulator. A value of 1 indicated that the leading vehicle complied with the warnings at the crossing, and a value of 2 showed noncompliance. When the train passed detector 2 (train has passed), vehicles passed through the crossing and the subject vehicle regained speed profile 2. If the subject vehicle did not obey the traffic rule, it passed through the crossing and touched detector 3. Then it was assumed that the following vehicle was forced to stop at the stop line.

results

results from Driving simulator

Figure 4 shows the speed profiles of the various types of devices on a straight road. Four speed profiles out of eight straight crossings were taken to feed the traffic simulator.

As the four sets of graphs show, drivers maintained speed until they were approximately 100 m from the stop line at passive crossings. The speed curves appeared similar between passive and active crossings on a straight road (high visibility), but approaching speeds at passive crossings were lower than at active crossings until about 75 m from the stop line when a train was approaching. This result suggests that drivers approach passive crossings more cautiously than active crossings. When the four speed profiles from passive and active crossings were compared for the distances between 70 and 25 m, large speed differences between devices were found at passive crossings while they were steady at active crossings. This result indicates that drivers are more influenced by the different warnings at passive crossings than at active crossings.

This trend also can be seen when no train is approaching. When drivers approach a crossing, they react to the warnings differently. Drivers begin to brake about 50 m from the stop line at passive crossings, whereas they gradually slow down at active crossings.

Figure 5 shows a speed profile at passive crossings for each device with standard deviation. Compared with the profiles for ITS devices, the speed profile of drivers at base control crossings has a larger deviation. This deviation suggests that crossings controlled by ITS devices lead drivers to more consistent driving behavior. These data

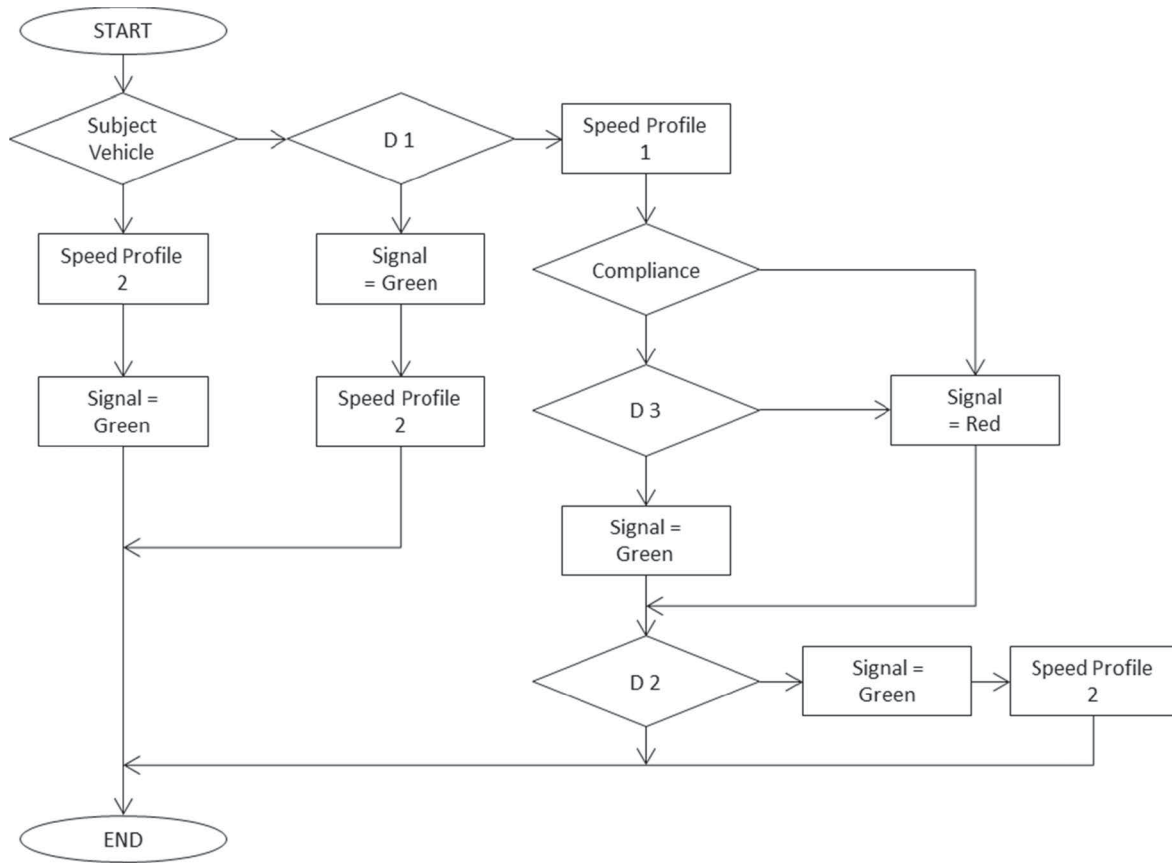


FIGURE 3 Flowchart of process in modified model (Speed Profile 1 5 speed when train approaches; Speed Profile 2 5 speed when there is no train; D 5 detector).

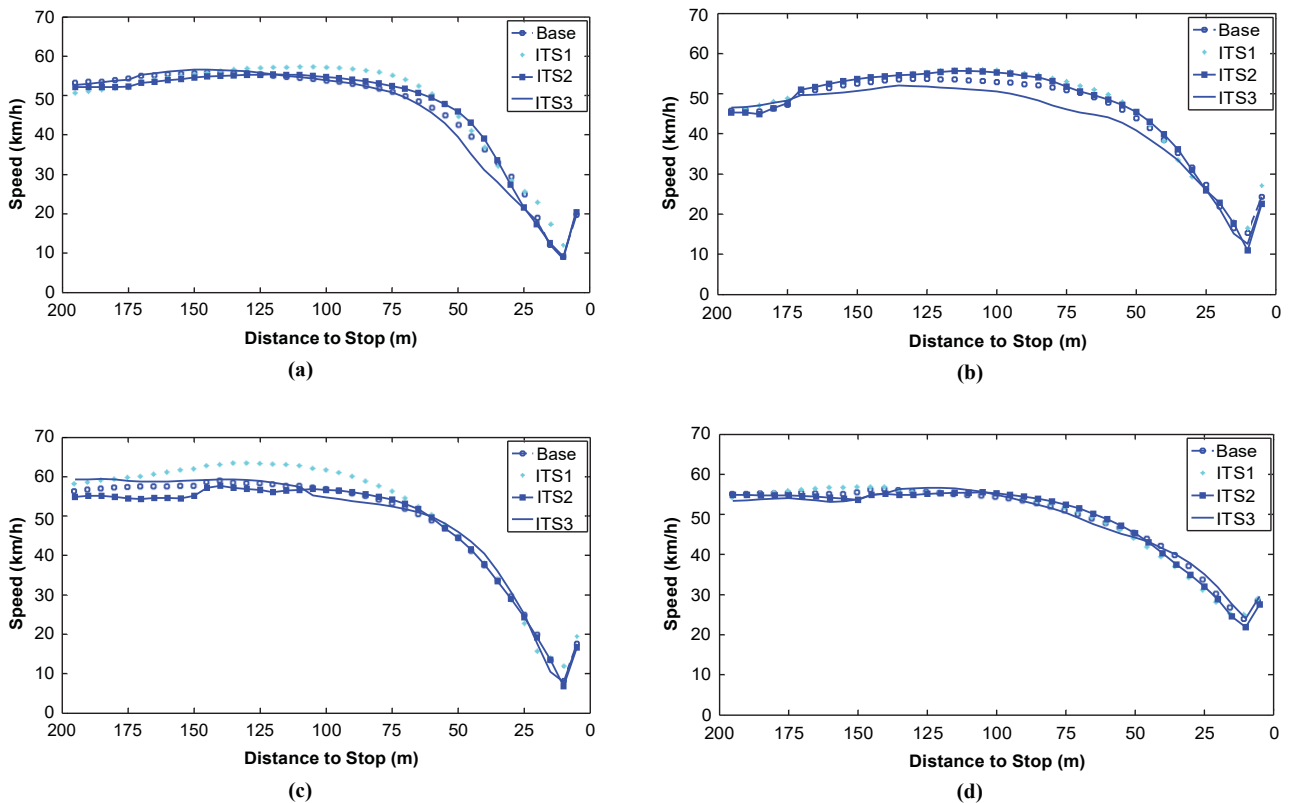


FIGURE 4 Speed profiles for crossings on straight road: (a) passive, train present; (b) passive, no train present; (c) active, train present; and (d) active, no train present.

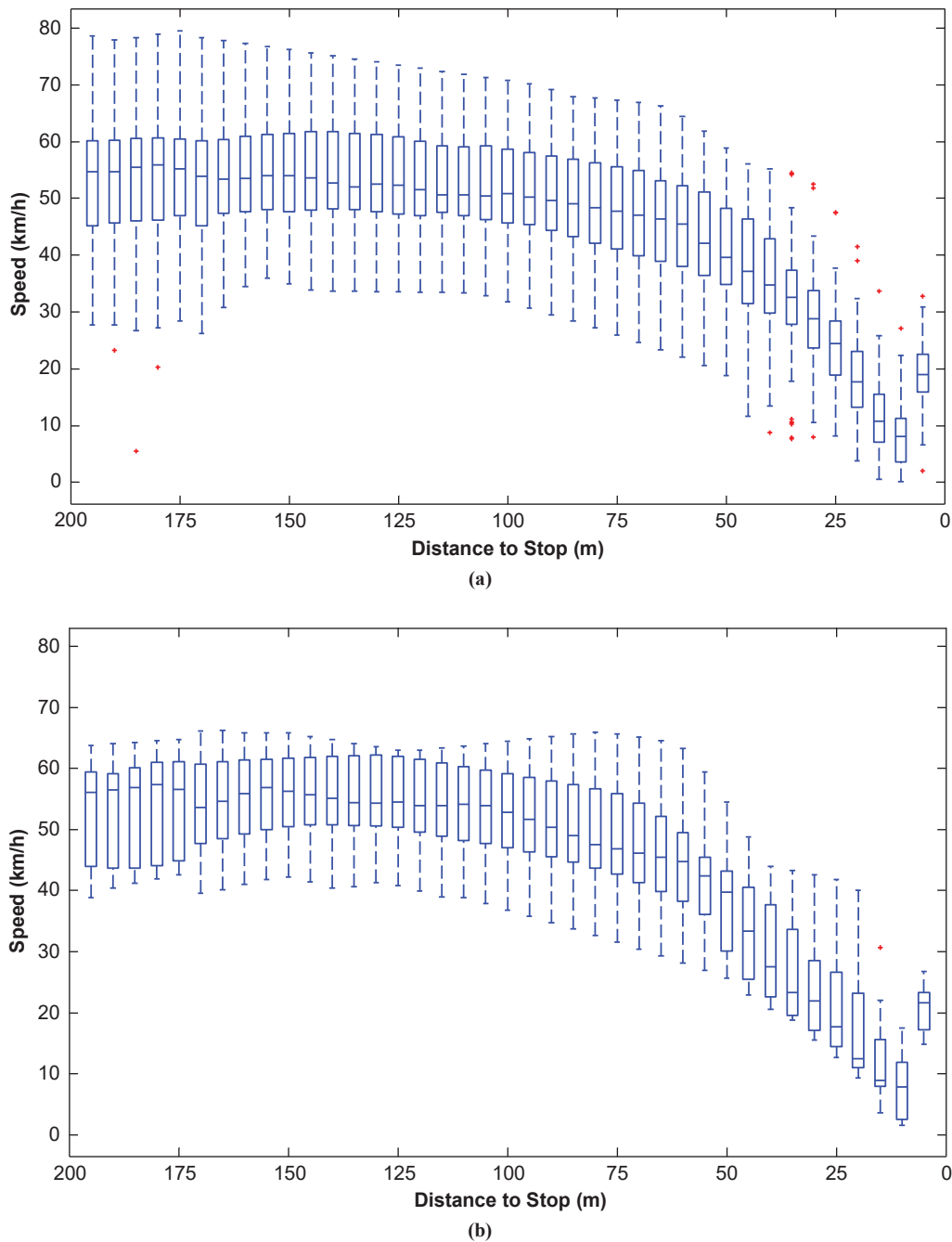


FIGURE 5 Speed distributions: (a) base and (b) ITS.

sets were used in the modified traffic simulation as important inputs (refer to the VISSIM setup section).

Table 2 shows the compliance rates for the four safety devices, for the two types of crossings, and with and without an approaching train. Noncompliance categories for passive crossings consisted of “Stopped almost completely,” “Left before the end of warning,” “Went before the train” and “Did not stop” and for active crossings were “Left before the end of warning,” and “Did not stop.”

The compliance rates for passive crossings were divided into a train approaching or not approaching, as drivers needed to stop at the stop line regardless of the ITS device’s activation. Drivers obeyed

the traffic rules at the active crossings more than they did at passive crossings. When a train was approaching a passive crossing, the ITS devices appeared to help drivers to stop to allow the train to pass, at 90%, 100%, 88%, and 86% for ITS1, ITS2, ITS3, and base, respectively. However, when no train was approaching, drivers relied on the devices and showed less compliance at rates of 57%, 61%, 59%, and 73% for ITS1, ITS2, ITS3, and base, respectively. Drivers approaching the active crossing positively responded to the warning by showing more than 90% compliance in all cases. Drivers approaching a crossing with ITS1 “Left before the end of warning” rather than “Did not stop” in the noncompliance category.

TABLE 2 Average Compliance Rate for Active and Passive Crossings

Compliance	Passive Crossing Device, by Presence of Train								Active Crossing Device with Train Present			
	Base		ITS1		ITS2		ITS3		Base	ITS1	ITS2	ITS3
	Train	No Train	Train	No Train	Train	No Train	Train	No Train				
Compliance (%)	86	73	90	57	100	61	88	59	95	90	100	100
Noncompliance (%)	14	27	10	43	0	39	12	41	5	10	0	0

results from traffic simulation

Delay is an appropriate measure not only for traffic efficiency but also for traffic safety. Here, the definition of delay is the time that speed is below a certain speed (e.g., 2 km/h) and not above a certain speed (e.g., 5 km/h). In particular, when some drivers experienced delays near railway crossings, they tended to change their driving behavior in three possible negative ways: they crossed the railway crossing illegally, made a U-turn to find an alternative route, or lost attention to warnings. Under such conditions unsafe practices may result.

Active Crossings

Train headway of 180 s only is an example of a peak time. Other cases, such as headway of 300 and 420 s, were also simulated and showed a pattern similar to that of the headway of 180 s. Base, ITS1, and ITS3 showed similar results in all measures including delay, stopped delay, the number of stops, and average speed for the tested route. The ITS2 had less traffic efficiency by showing a little more delay and several stops. This resulted in a lower average course speed.

As shown in Figure 6a, average delays for the different devices were similar, although there was a marginal difference for ITS2. When traffic volume increased from 800 to 1,500 vph, average delays for all devices linearly increased by approximately 35% at a headway of 180 s. However, when the train headway decreased (to 300 s), the increase in delay was less. This graph shows that when trains run

every 300 s, there is an approximate 20% delay increase between traffic volumes of 800 and 1,500 vph.

Figure 6b shows the distributions of average delay time for all cases at a headway of 180 s and traffic volume of 1,000 vph. In this case, the base and ITS3 crossings have a similar distribution, whereas ITS2 is located more to the left and ITS3 is located more to the right. All crossings are scattered in a range of about 4 to 8 s.

Figure 6c shows the number of stops that vehicle traffic has encountered when it has crossed the railway crossing. Unlike delay, the number of stops increases exponentially with traffic volume. Once the leading vehicle stops to obey traffic regulations, the following vehicles also have to stop. As vehicle volume increases, the number of stop-and-go situations increases.

Passive Crossings

The conditions for passive crossings were different from those for active crossings. In real situations, passive crossings are operated in areas of low traffic volume and low train headway. This study replicated as closely as possible what happens in real life. In the study, simulation runs were performed for 17 trains passing per day (10 h of operation) at different times against traffic flows of 200, 250, and 300 vph. Unlike active crossings, average delays for ITS devices were less than those without ITS devices, as shown in Figure 7. Because traffic volume was very low, delay was also low compared with that at active crossings.

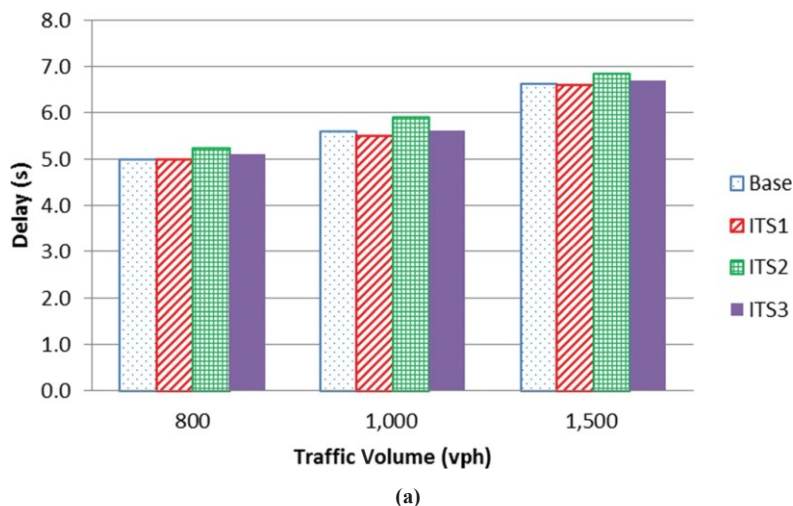


FIGURE 6 Results: (a) average delay per vehicle (s).
(continued on next page)

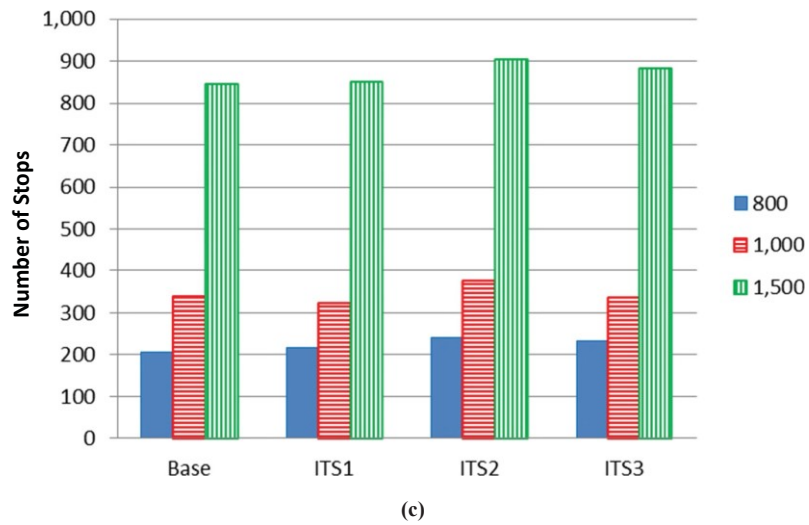
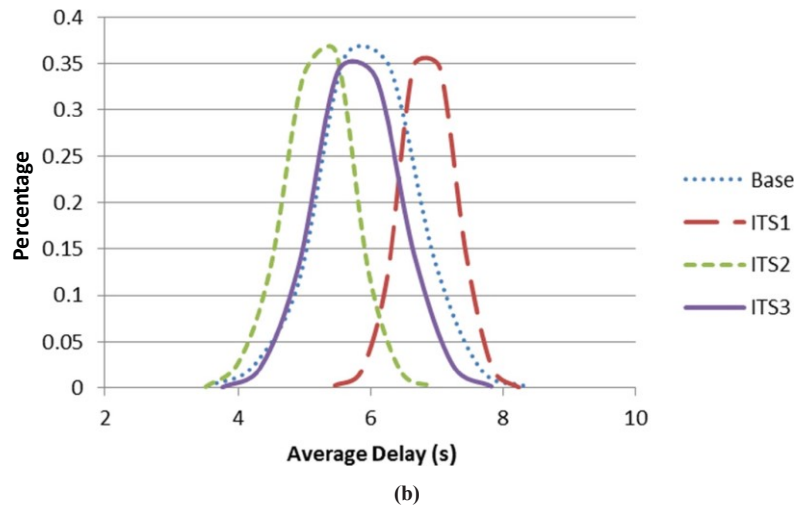


FIGURE 6 (continued) Results: (b) distribution of average delay for each device at 1,000 vph and (c) number of stops for each device by traffic volume.

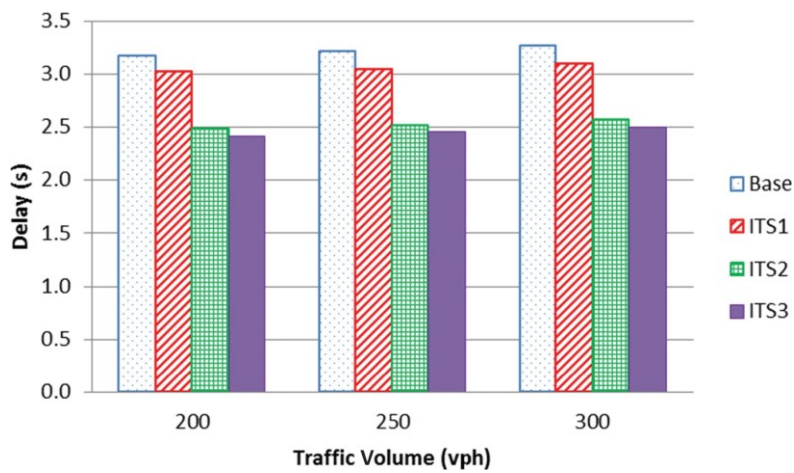


FIGURE 7 Average delay per vehicle (s) at 17 trains per day (10 h).

Because traffic volume and train headway are very low, the average number of stops per vehicle and average stopped delay per vehicle are close to 0. However, average speed at the passive crossings ranged from 52 to 56 km/h across different traffic volumes for each ITS intervention. Average speed at the active crossings ranged from 44 to 48 km/h. The ITS devices had a more positive impact on traffic performance at passive crossings than at active crossings.

Discussion of results

Three ITS interventions were tested in a driving simulator: a visual in-vehicle ITS, an audio in-vehicle ITS, and an on-road marker system. The results indicated that driver behavior was more influenced by passive crossings with ITS intervention than by active crossings. In general, when a train was approaching, the drivers slowed more at passive crossings than at active crossings. Large speed differences between devices were obvious at passive crossings, but they were steady at active crossings. This result indicates that drivers were more influenced by the various warnings at passive crossings than at active crossings. When a comparison was conducted among ITS devices, the speed profile of drivers toward ITS devices showed less deviation than the base case. This suggests that the crossings controlled by ITS devices led drivers to a more consistent driving behavior.

Both the visual in-vehicle ITS and the on-road markers ITS devices produced similar compliance rates at passive crossings. All ITS devices increased compliance rates when a train was approaching these crossings. However, because compliance rates at active crossings without ITS devices were already 100%, nothing further could be shown.

The results obtained from the traffic simulation for the urban region indicated that railway crossings equipped with ITS devices did not lead to significant changes for most traffic performance indicators at active crossings. Railway crossings with ITS2 (audio) had slightly increased delay and number of stops and decreased average speeds compared with other cases. These results show that implementing ITS devices does not have a great impact on traffic performance as all indicators were similar to the crossings without ITS devices.

The results of traffic simulation for the suburban region with low traffic volumes, with low train headway, and where passive crossings are normally implemented showed that the ITS devices improved the traffic performance with less delay time, a lower number of stops, and a higher compliance rate.

conclusions and recommendations

The research investigated the effects of three ITS approaches at level crossings: both in-vehicle (smartphone) and roadside warnings and protection systems. Driving simulator data were integrated with traffic simulation for assessing whether ITS can improve safety and efficiency at railway crossings.

Statistical models using historical data generally consider the occurrence of accidents between vehicles and a train. However, traffic simulation can quantify the impacts at a network level and can mimic not only how a lead vehicle responds to warnings but also what happens to the vehicles following it.

The safety outcomes for ITS systems have been compared with those for current safety systems (passive and active) at railway crossings. The outputs of the driving simulator experiments have been a

critical input for traffic simulation. The latter has been used to simulate realistic driving scenarios.

The transportation simulation results showed positive impacts for the introduction of ITS as a complementary system at railway crossings to ensure a better safety outcome for users at both active and passive crossings.

This research can be further improved by through more driving simulator experiments that would verify the results of speed profiles and compliance rates. Because the number of participants was low in comparison with the entire population, not all age groups or genders were equally represented. Therefore, data from a neighboring group were used to assume a few demographic categories. If more data for these underrepresented groups are collected, the results could be applied more confidently to the population. Alternatively, a binary logistic model based on demographic information and the type of crossings could be used to determine whether drivers tend to go through or stop when they are required to stop.

This research provided a promising methodology for using a driving simulator and a traffic simulation to evaluate railway crossing safety and efficiency. The ITS solutions tested in this research were similar to those considered by the Australian rail industry to complement current safeguards. Also, a network performance influenced by those driving behaviors was calculated by the modified traffic simulation. Because of the usefulness of traffic simulation, various scenarios including various traffic volumes, train headway, geography, and a proportion of transportation modes could be tested.

acknowledgments

This work was supported by the Cooperative Research Centre for Rail Innovation, established and supported through the Australian government's Cooperative Research Centres program.

references

1. *Railroad-Highway Grade Crossing Handbook*. FHWA, U.S. Department of Transportation, 2007.
2. Elvik, R., and A. B. Mysen. Incomplete Accident Reporting: Meta-Analysis of Studies Made in 13 Countries. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1665, TRB, National Research Council, Washington, D.C., 1999, pp. 133–140.
3. Mills, B. N., J. Andrey, and D. Hambly. Analysis of Precipitation-Related Motor Vehicle Collision and Injury Risk Using Insurance and Police Record Information for Winnipeg, Canada. *Journal of Safety Research*, Vol. 42, No. 5, 2011, pp. 383–390.
4. Barfield, W., and T. A. Dingus. *Human Factors in Intelligent Transportation Systems*. Psychology Press, New York, 2014.
5. Hallvig, D., A. Anund, C. Fors, G. Kecklund, J. G. Karlsson, M. Wahde, and T. Åkerstedt. Sleepy Driving on the Real Road and in the Simulator—A Comparison. *Accident Analysis and Prevention*, Vol. 50, 2013, pp. 44–50.
6. Yang, Q., R. Overton, L. D. Han, X. Yan, and S. H. Richards. The Influence of Curbs on Driver Behaviors in Four-Lane Rural Highways—A Driving Simulator Based Study. *Accident Analysis and Prevention*, Vol. 50, 2013, pp. 1289–1297.
7. Horberry, T., J. Anderson, and M. A. Regan. The Possible Safety Benefits of Enhanced Road Markings: A Driving Simulator Evaluation. *Transportation Research*, Vol. 9, No. 1, 2006, pp. 77–87.
8. Lenné, M. G., C. M. Rudin-Brown, J. Navarro, J. Edquist, M. Trotter, and N. Tomasevic. Driver Behaviour at Rail Level Crossings: Responses to Flashing Lights, Traffic Signals and Stop Signs in Simulated Rural Driving. *Applied Ergonomics*, Vol. 42, No. 4, 2011, pp. 548–554.

9. Larue, G.S., I. Kim, A. Rakotonirainy, L. Ferreira, and N.L. Haworth. Integrating Driving and Traffic Simulators to Study Railway Level Crossing Safety Interventions: A Methodology. In *Computers in Railways XIII: Computer System Design and Operation in the Railway and Other Transit Systems*, WIT Press, Southampton, United Kingdom, 2012, pp. 719–732.
10. de Winter, J., P. Van Leeuwen, and R. Happee. Advantages and Disadvantages of Driving Simulators: A Discussion. *Proc., Measuring Behavior 2012*, Utrecht, Netherlands, 2012, pp. 47–50.
11. Tey, L.-S., L. Ferreira, and A. Wallace. Measuring Driver Responses at Railway Level Crossings. *Accident Analysis and Prevention*, Vol. 43, No. 6, 2011, pp. 2134–2141.
12. Tey, L.-S., G. Wallis, S. Cloete, and L. Ferreira. Modelling Driver Behaviour Towards Innovative Warning Devices at Railway Level Crossings. *Accident Analysis and Prevention*, Vol. 51, 2013, pp. 104–111.
13. Rudin-Brown, C. M., M. G. Lenné, J. Edquist, and J. Navarro. Effectiveness of Traffic Light vs. Boom Barrier Controls at Road–Rail Level Crossings: A Simulator Study. *Accident Analysis and Prevention*, Vol. 45, 2012, pp. 187–194.
14. Ozbay, K., H. Yang, B. Bartin, and S. Mudigonda. Derivation and Validation of New Simulation-Based Surrogate Safety Measure. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2083, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 105–113.
15. Abdel-Aty, M., J. Dilmore, and A. Dhindsa. Evaluation of Variable Speed Limits for Real-Time Freeway Safety Improvement. *Accident Analysis and Prevention*, Vol. 38, No. 2, 2006, pp. 335–345.
16. Transport and Main Roads. In *Manual on Uniform Traffic Control Devices*. FHWA, U.S. Department of Transportation, 2009.
17. *Current Queensland Driver Licences*. Department of Transport and Main Roads, Queensland, Australia, 2010.
18. Tey, L.-S., I. Kim, and L. Ferreira. Evaluating Safety at Railway Level Crossings with Microsimulation Modeling. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2298, Transportation Research Board of the National Academies, Washington, D.C., 2012, pp. 70–77.
19. Kim, I., L. Ferreira, L. S. Tey, and G. Wallis. Integration of Driving Simulator and Traffic Simulation to Analyse Behavior at Railway Crossings. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit*, Vol. 227, No. 5, 2013, pp. 427–438.

The Standing Committee on Railroad Operational Safety peer-reviewed this paper.